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ABSTRACT

The difficulties and differences of the Hebrew speech of nine children (ages 7 through 11) with severe hearing impairments were compared with the speech of seven children (ages 4-8) without hearing impairments. Each child was asked to name the objects in 20 colored pictures. From the 20 objects, words were selected which included the five main vowels of the Modern Hebrew phonological system in unstressed and stressed syllables. The study analyzed the children's production of 10 syllables from six Hebrew nouns (five bisyllabic and one trisyllabic) in terms of the features of oral speech that are characteristic of individuals who have deafness, including: pitch; minimum and maximum values; ranges and standard deviations; and the duration of spoken segments. The following distinct differences between the two groups were found: (1) average pitch values were higher in the children with hearing impairments; (2) maximum pitch in accented vowels of children with hearing impairments was higher; (3) pitch ranges of children with hearing impairments were higher; (4) standard deviation values were somewhat higher in children with hearing impairments; and (5) vowel durations were larger in children with hearing impairment. An analysis of accent differences was also conducted. Attached figures show details of the comparison. (Contains 18 references.) (CR)

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ED 399 720

VOICE CUES IN HEARING AND HEARING IMPAIRED HEBREW SPEAKING CHILDREN

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ABSTRACT

This paper focuses on features of pitch and duration of the speaking voice in hearing-impaired and hearing Hebrew-speaking children. Subjects were 7 hearing kindergarten children (5, age range: 4-5 + 2 age range: 7-8) and 9 severely hearing impaired school children (age range: 7-11), native speakers of Hebrew, from around Haifa. Analyzed were 10 syllables from 6 Hebrew nouns, 5 bisyllabic and one trisyllabic. The above features are among the most salient cues marking deaf speech, and our findings show many differences in these areas. The results are discussed for Hebrew and are compared to the literature on other languages, mainly for hearing-impaired children. Suggestions for voice training and further research are made.

INTRODUCTION

A major problem of the hearing impaired (HI) is the quality of their oral speech. Pre-lingual HI children cannot use their hearing system for spontaneous language acquisition. Often only at school do they produce real speech. Their speech is then often awkward and markedly different from that of the hearing (H) children. This fact requires special language and speech training for many long years.

In this paper we focus on a few features of oral speech which have been described in the literature as characteristic of deaf speech, since they are very fundamental components of speech signals: pitch as revealed in mean pitch values, minimum and maximum values, ranges and standard deviations, as well as the duration of the spoken segments.

Pitch control is very important for oral speech in any language. Some languages use different tones (that is, pitch levels) as semantic-syntactic segments. Pitch modulations also form intonation which has numerous

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linguistic and para-linguistic roles. In this work, however, we use isolated words rather than sentence intonation and examine segmental rather than supra-segmental pitch.

Pitch range is the range between the highest and lowest frequency which the speaker's voice has reached in the measured utterance. Pitch ranges refelect the functioning of the speaker's glottal vibrations: larger pitch ranges within an element, for example, imply weaker control of the vocal cords, and HI are not considered able to control them as efficiently as H people do.

Standard deviations (STD) values reflect individual variations within a group of observations. Larger STD values indicate more fluctuations and greater differences than small STD values. We examined the STD values of both pitch and duration values of our subjects.

As far as we know the topic we are studying here has not been studied for modern Hebrew in this manner. Thus, this study can contribute to the linguistic education of HI and deaf children in Israel. At the same time it will be interesting to compare our findings with the literature on other languages, in order to see similarities and differences some of which may be due to language-specific features.

In the following sections we describe the subjects and the experiment, and then the findings and our conclusions.

POPULATION AND METHOD

Subjects included two groups of speakers: seven hearing kindergarten children (5, age range: 4-5 + 2 age range: 7-8) and nine severely hearing-impaired school children (age range: 7-11), native speakers of Hebrew from the Haifa area.

Due to differences in language acquisition duration of each of these populations, a group of younger H children was considered somewhat more adequate for comparison with the older HI group. The various ages of the HI children are also perhaps not very indicative of their phonetic achievements, since 4 of them were at the time in 1st grade, 2 in the 4th (11 y. old) grade and 6th (13 y. old) grades, the others being between these grades. In all cases, however, the grade in which the HI children studied was lower than the expected age and grade of the matching H children.

Table 1. The Hearing subjects

Name	Age	Sex
Oren	5	m.
Liron	5	f.
Maya	5	f.
Barak	4:6	m.
Gal	5	m.
Hen	8	f.
Naama	7:6	f.

The study required the following steps:

First, each child was individually recodred in the kindergarten (H children) and in Shema' (HI). We elicited the utterances by asking each subject to name the objects in 20 coloured pictures. Each child identified him/herself by their given names before the naming process which was recorded twice. The objects in these pictures were familiar to the children, and no difficulty was noted in this task. From these 20 objects we selected those words which include the five main vowels of the Modern Hebrew phonological system in unstressed and stressed syllables. These vowels are: /I, e, a, o, u/.

The analysis was made for ten syllables from six Hebrew nouns, five bi-syllabic and one tri-syllabic. The syllables were: **/bi - gi - ḥe - le - da - ba - co* - ko - bu - du/** used in the Hebrew words: **/bu'ba/** 'doll', **/'dubi/** 'teddy bear', **/da'gim/** 'fish pl.', **/'leḥem/** 'bread', **/'kova/** 'hat' and **/'šokolad/** 'chocolate'. The speech analysis system "Signalyze" was used to extract from this material (among other features) the values of pitch, min.-max. pitch values, pitch ranges and pitch standard deviations and vowel durations. Statistical analysis of these elements inter-group comparison and within speaker variance yielded the results reported below.

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*the grapheme 'c' is used only to distinguish /ko/ in /'šokolad/ from /ko/ in /'kova/.

Table 2. The Hearing Impaired Subjects

Name	Age	Sex	Ear	Audiometry					
				250	500	1000	2000	4000	MPS (250,500,1000)
1. Ortal	9	f.	r.	90	100	+	+	+	(undetermined)
			l.	80	95	105	105	105	
2. Shahar	8	f.	r.	90	95	105	105	+	102
			l.	75	85	105	110	+	100
3. Lea	7	f.	r.	80	95	110	120	110	108
			l.	80	110	110	95	75	105
4. Sal'it	8	f.	r.	85	100	110	+	+	(undetermined)
			l.	90	100	110	+	+	(undetermined)
5. Ori	8	m.	r.	90	100	110	110	+	(undetermined)
			l.	80	95	105	110	+	103
6. Shay	11	m.	r.	85	95	(100)	105	+	100(estimated)
			l.	95	105	(100)	110	+	100(estimated)
7.Maxim	13	m.	r	80	100	+	+	+	(undetermined)
			l.	80	90	110	+	+	(undetermined)
10Ma'or.	7	m.	r.	95	95	100	110	+	102
			l.	95	95	100	110	+	102
11. Ido	11	m.	r.	90	95	110	110	105	105
			l.	90	95	110	110	110	105

FINDINGS

Table 3 is a summary of the statistical means of the measured phonetic values of unaccented and accented vowels in the two groups of subjects.

Table 3 shows distinct differences between the two groups with the vowels classified to accented and unaccented groups. Figs. 1, 2 demonstrate waveforms and formants' differences in the vowel /i/ as pronounced in the word /da'gim/ by a H and a HI child, and Figs. 3, 4 present waveforms and pitch movements in the vowel /i/ of the word /dubi/ and the word /dagim/ by a H and a HI child. The charts in Figs. 5-8 show four aspects of the statistical results: mean, range, STD and

duration. The main features of these differences are described in the following paragraphs.

Table 3. Average values of the Hearing and Hearing Impaired groups by parameter and by accentuation

Group	Accent	Average pitch (Hz)	Min f (Hz)	Max f (Hz)	Range f (Hz)	STD	Duration t (ms)
H	-	245.35	201.5	296.79	95.294	22.23	124.4
H	+	254.37	206.6	303.74	97.142	21.88	189.8
HI	-	302.51	251.9	357.95	95.00	28.60	205.8
HI	+	307.46	240.1	379.37	139.24	31.71	251.3

Average pitch

Average pitch values are higher in the HI group by about 50 Hz than in the H group. This contradicts the fact that pitch descends in children simultaneously with increasing age. It is, however, in accordance with what is known about many HI children's pitch.

Minimium pitch values

Minimum pitch values do not show much within-group variance (depending on the accent), though it exists. It is curious, though, that accented vowels in the HI group have a somewhat lower minimum average pitch than the unaccented vowels.

Maximum pitch

Maximum pitch in accented vowels of the HI group is (re-latively) higher than that of the H group. That is to say, the difference between maximum pitch in unaccented and accented vowels in HI is larger than that in the H group.

Pitch ranges

Pitch ranges of the HI group reveal absolutely and relatively higher values (than those of the H group) and this in the accented vowels more than in than in the unaccented vowels. This may be due to the fact that HI children exert conscious but uncontrolled efforts to accentuate the accented vowels using all the physical means: pitch changes, duration

(and probably also intensity, though this was not measured here). This is certainly much more obvious than in the H subjects.

STD

STD values are somewhat higher in the HI than in the H group, but not significantly. This fact might also be probably partly explained by the higher pitch values of the HI group. However, the ratio of STD in unaccented-to-accented vowels in the H is much smaller than the HI group.

Vowel durations

The absolute values of vowel durations are larger in the HI group than in the H one, corroborating what is known about deaf speech in other languages. Both groups distinguish between unaccented and accented vowels in that unaccented vowels are shorter than accented ones. In the HI this is not at a level of statistical sifgnificance, however, since in two of the five vowels unaccented vowels are a little longer than accented ones.

Table 4 summarises the P values of significant effects of the mixed model used for the statistical analysis of the data for each variable on its own (group, vowel, accent) and in various combinations.The significance level varies, however, as can be easily observed. The asterisks mark the most significant values.

Table 4. P Values of the Significant Effects of the Model

	Group	Accent	Vowel	Gr*Ac	Gr*Vow	Ac*Vow	Gr*Vow*Ac
AV	.0059	---	.0341	---	*.0001	---	---
MIN	*.0004	---	.1209	---	.0038	---	---
MAX	.0029	.0176	*.0002	.0841	*<.00001	.0944	---
RANGE	.1456	*.0081	.0456	.0123	*.0009	---	---
STD	.0422	---	.0691	---	.0194	---	---
DUR	.0555	---	.0171	---	*<.00001	.0145	---

Detailed analysis by accent

Average Pitch

Statistical differences were found between the groups. These differences are expressed in different internal groupings of the vowels in each group. These arrangements (which we quote for each parameter) reflect the statistical distance from the model. Thus, for the parameter "average pitch", unaccented vowels of the H group can be arranged from lowest to highest pitch (rising order) in the following 2 groups: /i, e, u/ /o, a/ while for the unaccented vowels of the HI group the vowel will form the following groups: /e, o/, /a, u/, /i/. In accented vowels, the H group does not reveal significant differences, while in the HI the differences are marginally significant, with the group order /e, e, a/, /u, i/.

Minimum Pitch

The statistical tests for this parameter did not reveal differences in the unaccented vowels. Still there is a difference between the groups, the HI's Min. average value is higher by about 50 Hz than that of the H group. The minimum values in the accented vowels, however, show marginally significant differences between the two groups. The arrangement of the vowels in the H group (in rising order of pitch values) is /i, a/, /u, e/ /o/, and in the HI group: /e/, /o, a, u/, /i/.

Maximum Pitch

For unaccented vowels in this parameter, gradual differences were found between the vowels in the H group: /i, u, e, a, o/ and the HI: /e, o, u, a, i/. For each group the accented vowels in this parameter differed, so that the vowels (in rising order) form the following groups: H: /a, e/, /i, u/, /o/; HI: /e, o/, /u, a/, /i/. These facts indicate the existence of both inter-group and intra-group differences in maximum pitch values. The main source of these differences is apparently /i/, which is inherently high, and in HI's speech is known to be even more prominently high.

Pitch Ranges

Pitch ranges of the H in un-accented vowels are marginally significant, with the following internal grouping of the vowel groups (in rising order): /i, u, a/, /e, o/. For the HI group the differences in unaccented vowels are not marginal, and the grouping is: /e/, /o/, /u/, /a,

Range values:

The most significant difference is due to accent (though we examined inter-group differences without taking this parameter in account). A different effect was also found for various vowels. This difference is different for each group.

STD values:

No significant effect was found for accent. There are differences between the vowels. STD values of the vowels are different for each group: for the H they are in the order: /a, u/,/e, i/,/o/; for the HI they are: /o, u, e, a/, /i/.

Duration values:

Inter-group difference was observed only depending on accent. Accented vowels are significantly different from unaccented ones. The difference in vowel ranking by accent was the following: in unaccented vowels: /a/, /o, u, e/, /i/, and in accented vowels: /u, e, o/, /i, a/.

DISCUSSION AND CONCLUSIONS

In the literature various studies deal with developmental features of H children (e.g., DiSimoni 1974a,b, Tingley and Allen 1975, Kent 1976, Smith 1978, Kent and Forner 1980, Flege 1982, Beardsley and Cullinan 1987). Klatt (1976) reviewed studies of durational patterns in adult speech. The features studied by us have been described as typical of deaf speech for prelingually deaf adult subjects as well as those postlingually deafened (e.g., Ball and Faulkner 1989, Ball, Faulkner and Fourcin, 1990, Cowie and Douglas-Cowie, 1992, Ling 1976, Maassen and Povel 1984, McGarr and Osberger 1978, Monsen 1984). La Bruna Murphy, McGarr and Bell-Berti (1990) studied lexical stress features produced by congenitally deaf children and their effects on the H.

These works deal mainly with English, whereas our study deals with kindergarten and young Hebrew-speaking school-children about whom few studies exist. For Hebrew Amir (1995) gives results of H 9-12 years old students' vowel means, STDs and durations, but they are older than our H group. Moreover, his results cannot be directly compared with ours, since they do not analyze separately unaccented and accented vowels as we did in the present study. His statistical results do distinguish between boys and girls (as well as adult female and male subjects) which we did not. The average pitch range of the five vowels

i/. In the accented vowels, there are differences in ranges of vowels, with /i/ (of /gi/) the highest value in both H and HI groups. In the H group the average range is about 96 Hz, while in the HI it is about 115 Hz.

Standard Deviations

In this parameter for unaccented vowels no inter-group significant difference was found, though the average STD of the HI group is higher (28.5) than in the H group (about 22). In the accented vowels, /gi/ had relatively higher values than the other vowels in both H and HI groups. The average STD in the accented vowels of the H group was about 17 and in the HI about 27 - a trend similar to the results of the unaccented vowels, though with a larger difference between the groups.

Duration

The statistical tests reveal inter-group differences in the unaccented vowels. There are also inter-vowel differences in each group. In the unaccented vowels of the H group the order of grouping (from lowest to highest values) is: /a, o/, /u, i/, /e/ and for the HI /u, o, a, e/, /i/. (This means that in the H /he/ and in the HI /bi/ are the longest vowels relative to the others.) In the accented vowels the order of vowels is: /e, u, o/, /a, i/ without group differences. It should be noted that trying to cancel accent effect (testing inter-group differences only) did not yield any group effect; only accent-affected vowel effects were found (±accent).

Detailed analysis by groups

(H vs. HI, without considering accent)

Average pitch:

No effect was found; H and HI groups show different ranking of the vowels: H: /i, e/, /a, u, o/; HI: /e, o/, /a, u, i/.

Minimum values:

No effect was found; H and HI groups show different ranking of the vowels: H: /i/, /e, u, a/, /o/; HI: /e/, /o, a, u/, /i/.

Maximum values:

There is a significant difference between the two groups (H, HI) and an effect for the interaction of group by vowel. There is a marginal effect for the interaction of accent and vowel. This effect is different in each group.

for both boys and girls in Amir (1995) is 254 Hz (lowest, in girls) - 276 Hz (highest in boys). In our study the average pitch of theH group is 245 Hz and 254 Hz in un-accented and accented vowels respectively. These values are within the average range of Amir's (1995) study. The HI group has a considerably higher average pitch, however, in our study - above 300 Hz.

Also duration differences are large between the H and HI groups in our study. Amir's study shows shorter durations for both boys and girls than our results (there boys' min. duration is 92.6 ms. and girls' max. duration - 127.15 ms.).

Here we should take into account that tempo (speech rate) develops with age, and this skill is much more developed in 9-12 year-old children than in 4-5 years old ones or even the two 7-8 year old girls in our H group. However, the HI some of whom were at the same age range as Amir's subjects, had even longer durations than our younger H children (cf. Table 3, above).

Our findings need to be verified by more subjects but basically they confirm what has been found for other languages: Differences in speech quality and naturalness between H and HI subjects are great and are therefore easily perceived by H liseners. Some of the results were expected:

1. Pitch and duration have relatively and absolutely larger values in the HI group than in the H group.
2. Pitch ranges are larger in the HI than in the H group
3. Fluctuations in values are greater in the HI group than in the H one as STD values indicate.

Likewise, note the following observations:

4. Most of these results are due to higher maximum pitch values in the HI group.
5. Individual vowels are the source of higher pitch, mainly /i/ in the HI. (Indeed, /i/ is also known to be inherently higher than other vowels).
6. Individual differences in HI speakers' oral speech are large as STD values show and are due to personal skills, extra-linguistic parameters, as well as different acquisition methods and periods.
7. An important finding is that lexical stress (accent) is a major factor distinguishing between Hebrew HI and H speech, since classification by

accent yielded most of the statistically significant differences between the groups and vowels.

Since congenitally HI children lack auditory feedback, learning oral speech requires a much longer period with them than with H children. This usuallyl delays the HI children's language acquisition period along with their cognitive development. These facts are part of the motivation for total communication or sign language-based education methods for the HI.

However, if one of the educational goals is to enable HI children acquire oral speech with more or less near-normal speech quality, apparently much more effort and time need to be put into training oral speech than is usually done (at least as demonstrated by our subjects). Much more training by use in real life should also be encouraged so that the HI child may acquire fluency and agility in the oral language, as others do when learning to master a new (foreign) language.

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Figure Captions

Fig. 1. Wave form and Formants of /i/ in the word /da'gim/ by a H child

Fig. 2. Wave form and Formants of /i/ in the word /dagim/ by a HI child (sounds /gia/)

Fig. 3. Wave form and Fo of /i/ in the word /dubi/ by a H child

Fig. 4. Wave form and F0 of /i/ in the word /dagim/ by a HI child

Fig. 5. Average means of H and HI children in accented and unaccented vowels

Fig. 6. Range means of H and HI children in accented and unaccented vowels

Fig. 7. STD means of H and HI children in accented and unaccented vowels

Fig. 8. Vowel durations of H and HI children in accented and unaccented vowels

Fig. 1. Wave form and Formants of *i* in the word *da'gim* 'fish pl.' by a H child

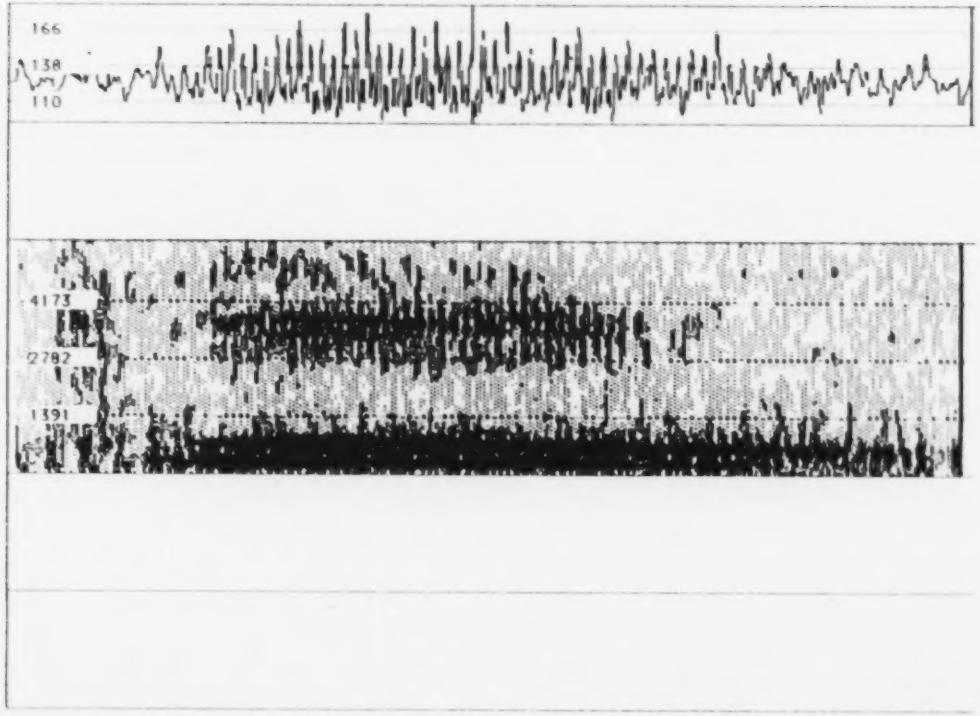

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Fig. 2. Wave form and Formants of /i/ in the word /dagin/ by a HI child (sounds /gia/)

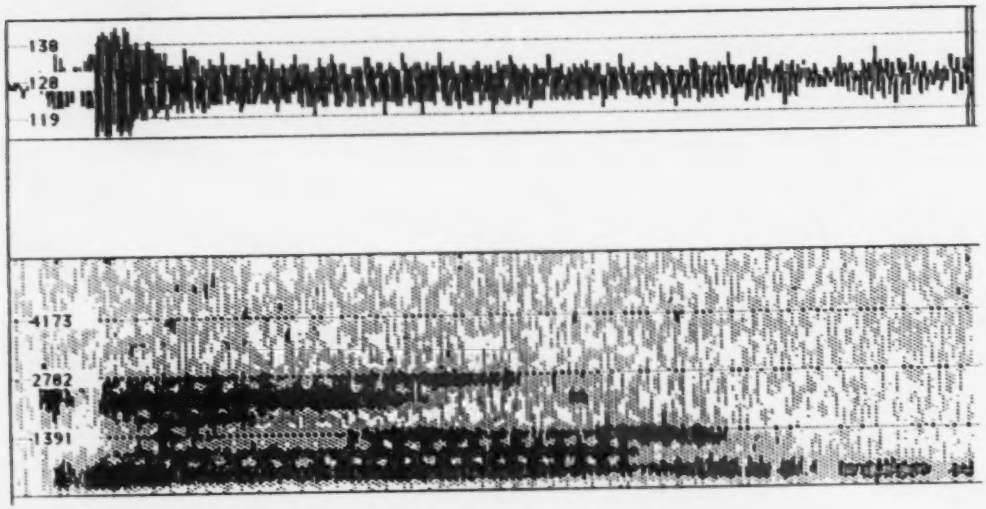

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Fig. 3. Wave form and Fo of /i/ in the word /dubi/ by a H child

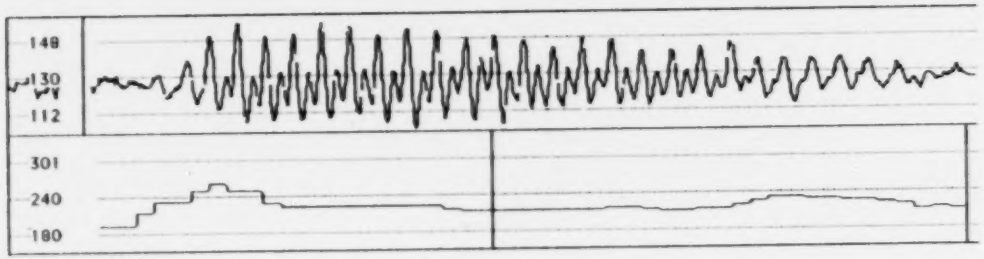

Fig. 4. Wave form and F0 of /i/ in the word /dagim/ by a HI child

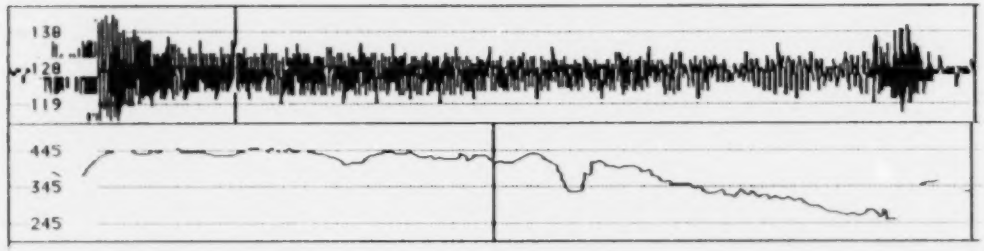

Fig. 5. Average means of H and HI children in accented and unaccented vowels

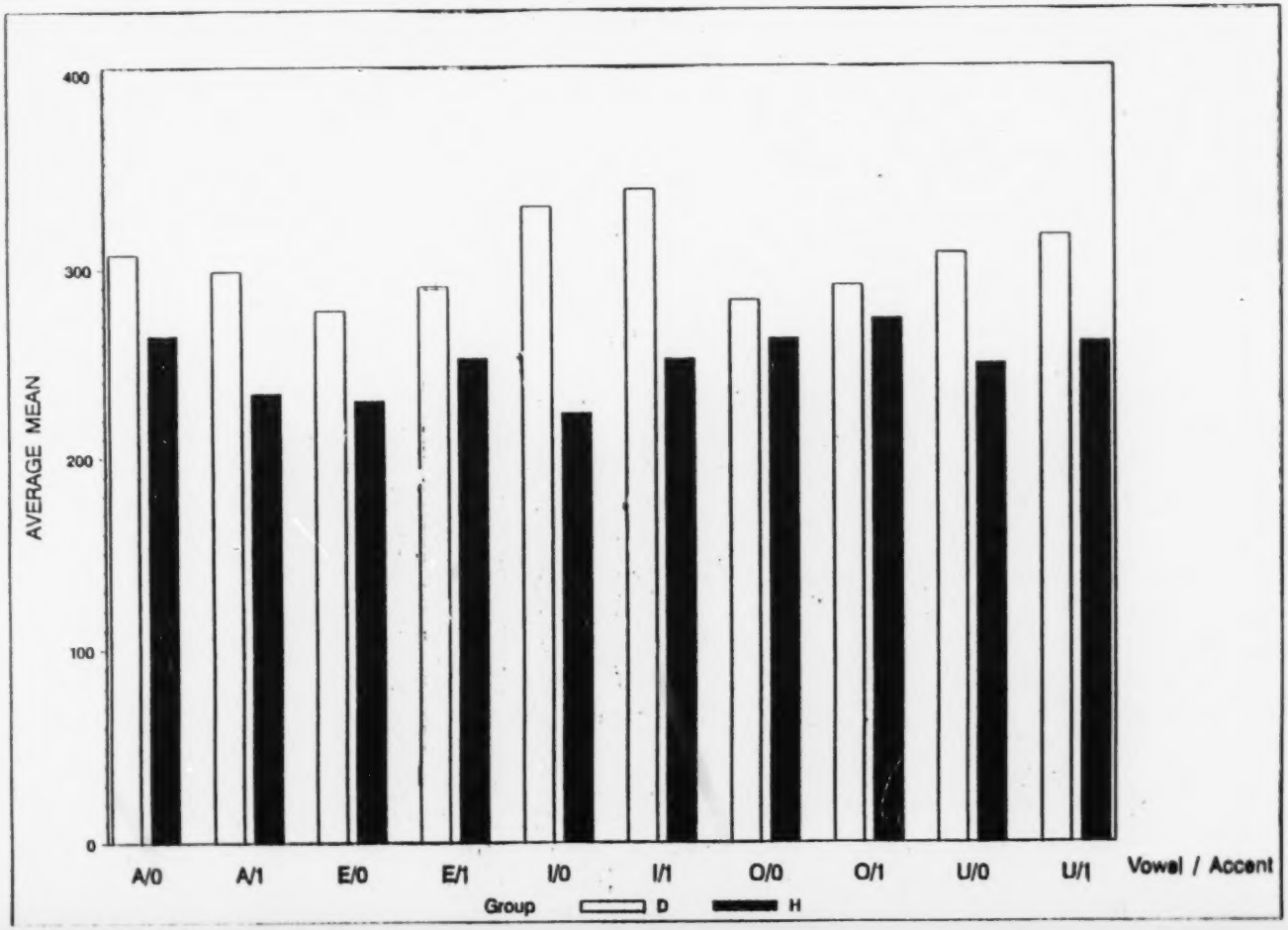

Fig. 6. Range means of H and HI children in accented and unaccented vowels

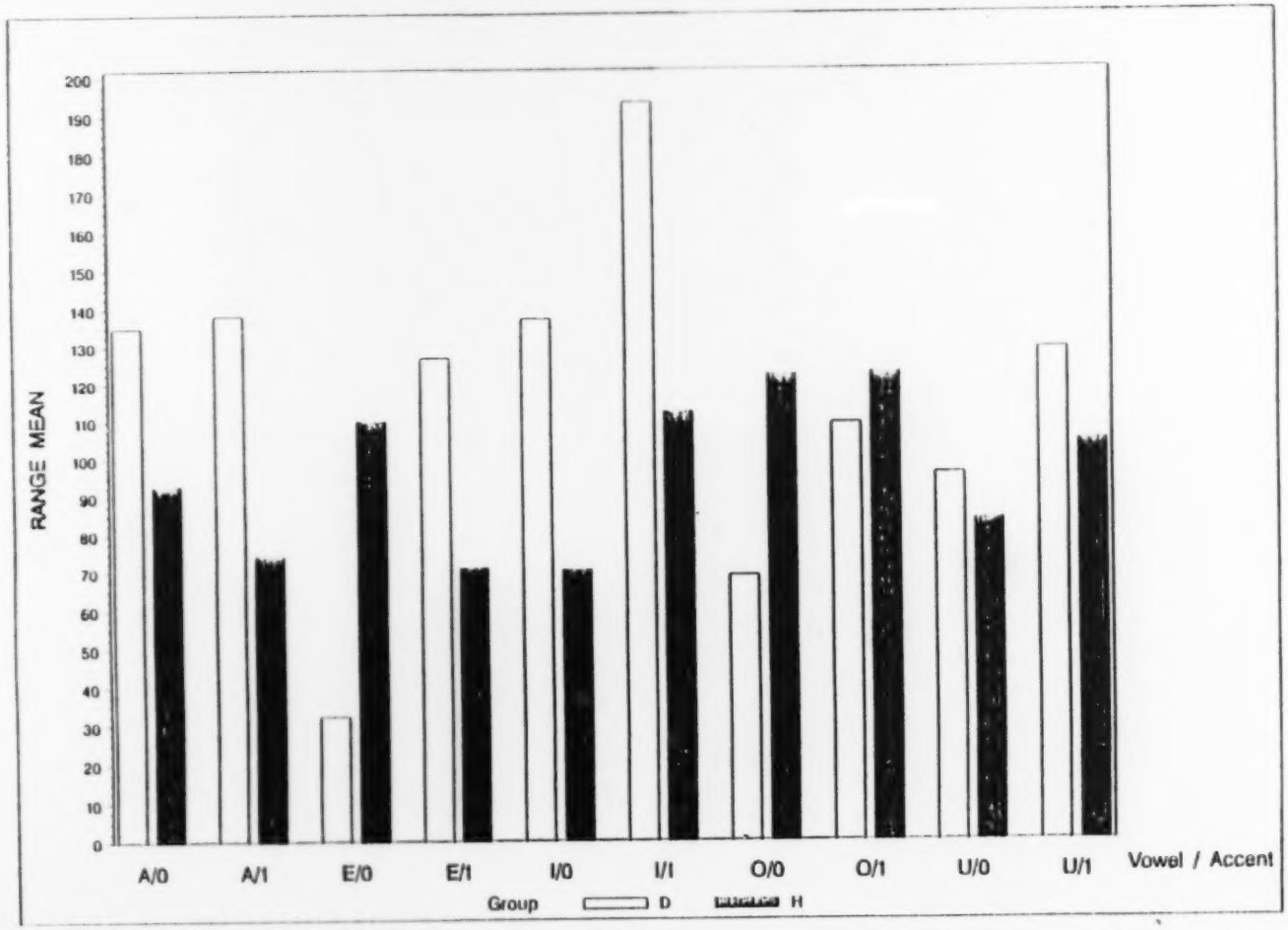

Fig. 7. STD means of H and HI children in accented and unaccented vowels

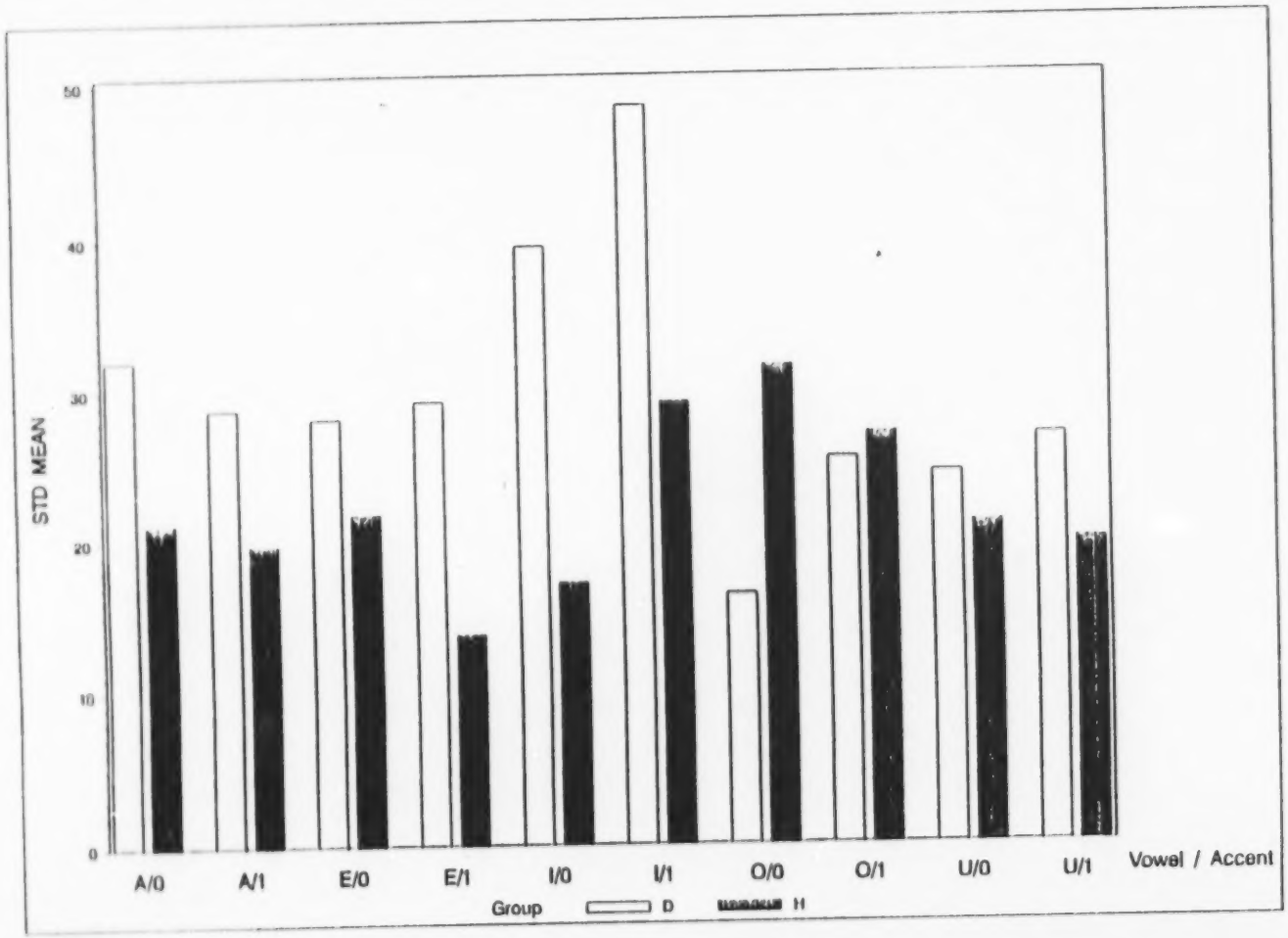

Fig. 8. Vowel durations of H and HI children in accented and unaccented vowels